OSSE OBSERVATIONS OF COSMIC GAMMA-RAY BURSTS

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ABSTRACT

The Oriented Scintillation Spectrometer Experiment detected over 80 cosmic γ-ray bursts from mid-April to late November 1991. Data at 16 ms resolution were accumulated from its large-area NaI shields in response to BATSE triggers. Rates in excess of 5000 cts/16 ms were observed from the 1991 May 3 burst. Bursts on June 1 and August 7 were observed in the spectrometer's aperture. Preliminary information on both the spectrum and location of the source of the June 1 burst are provided. Plans for future observations and analyses of bursts are discussed.

INTRODUCTION

The Oriented Scintillation Spectrometer Experiment (OSSE) on the *Compton Observatory* incorporates a variety of detection and measurement capabilities for cosmic γ-ray bursts. OSSE consists of four independently oriented phoswich scintillation detectors with both passive and active shielding for reducing background and defining its aperture[1,2]. Figure 1 shows a single OSSE detector. Its principal element is a 33 cm diameter phoswich (effective area 480 cm^2 at 511 keV), consisting of 10.2 cm thick NaI and 7.6 cm thick CsI crystals, optically coupled to each other and viewed by seven photomultiplier tubes.

The CsI and NaI pulses are electronically separated by pulse-shape discrimination, thus providing a compact anti-coincidence system for charged particles and background γ-rays. Spectra covering the range from 0.05 to >200 MeV are typically accumulated with a resolution of $\sim$16.4 s; event-by-event data covering limited spectral ranges with integration times $\geq$0.125 ms and rates in broad ranges with integration times $\geq$4 ms may also be available. A tungsten collimator above the phoswich defines a 3.8° x 11.4° FWHM aperture. Surrounding the phoswich and collimator is a NaI annular shield, made up of four segments and having the capability of providing 0.1 MeV to 8.0 MeV spectra of about 1/3 of the bursts. The projected areas of the shields for each detector range between 1000 and 1750 cm^2, depending on incident angle.

Figure 1. An OSSE Detector.

Only a few bursts per year are expected to fall within the field of view of the OSSE central detectors, which have 5σ sensitivities of $\sim$2 x 10^{-7} erg cm^{-2} (0.05 - 0.30 MeV) for bursts shorter than 16 s in duration. On the other hand, the annular shield segments should detect $\geq$50% of all bursts observed by BATSE with emission >0.1 MeV. Data from each segment are typically recorded at 2 s resolution and yield sensitivities to bursts $\sim$ 1 x 10^{-7} erg cm^{-2}(5σ). In response to a BATSE trigger signaling the detection of a fast transient, OSSE accumulates the summed rate from all 16 shield elements into 4096 time bins. The rates are stored in 16 ms bins from $\sim$4 s prior to the BATSE trigger to $\sim$61 s after the trigger (the accumulation, resolution, and pre-burst history times are adjustable).

A total of 176 BATSE cosmic-burst triggers were received by OSSE from April 15 through November 29, 1991. Data from 140 of these events have been studied; data from the remaining events have not been recovered to date, but may be with additional processing. Of these 140 events, 83 produced significant response in the total OSSE shield rates monitored at 16 ms resolution. Thus $\sim$ 60% of BATSE burst events have been recorded by OSSE. OSSE's central detectors recorded significant responses to at least five of the events (not all bursts have been searched for central detector response). These events occurred on 1991 May 3, June 1, August 7, August 14, and November 18. The events on June 1 and August 7 were each observed within the apertures of two of the OSSE detectors; the remaining events were so intense that significant radiation penetrated the shields. The number of events observed in OSSE's aperture is consistent with what is expected. The full aperture of each detector subtends about 0.4% of the sky; therefore based on a total of 176 bursts, one would expect to see $\sim$0.7 events in each detector. Because the detectors typically view two to three different fields at the same time, one would expect about two of the bursts to be directly observed in OSSE's central crystals. In the next sections we describe the OSSE observations of the May 3 and June 1 bursts.

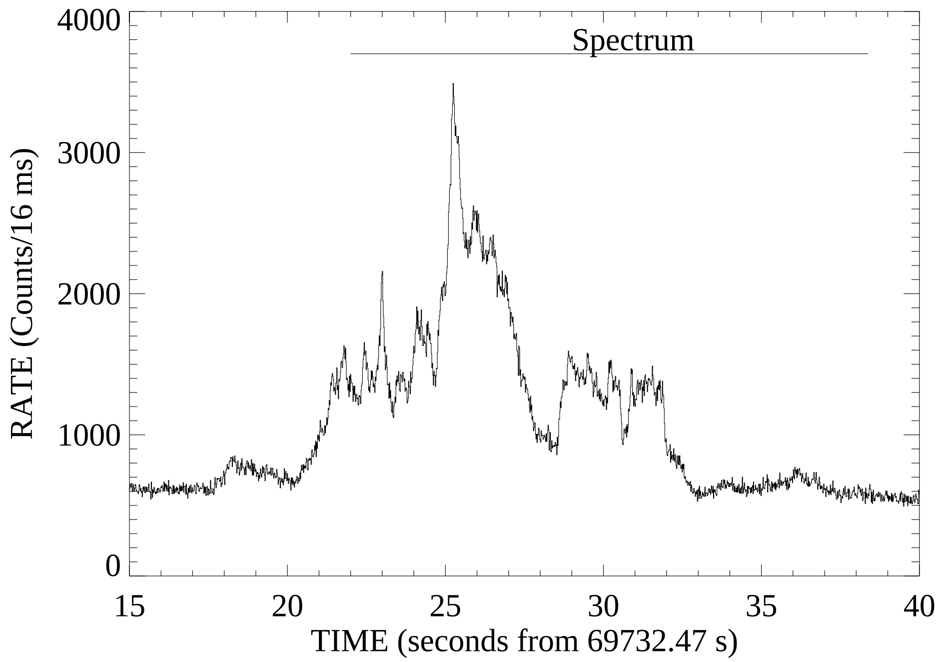

Figure 2. Count rates >100 keV recorded at 16 ms resolution by OSSE annular shields from the June 1 burst. Interval in which spectrum in Fig. 3 was accumulated is shown.

The most intense portion of the burst history recorded >100 keV by the summed shield elements of OSSE is displayed in Figure 2. BATSE triggered on a smaller gradual peak at 4 s (not shown on the figure). Sharp temporal structures are observed over an apparent pedestal covering about 11 s. Significant variations on timescales of 16-32 ms, with a peak rate of $\sim$3000 counts in 16 ms are observed. During the time of the burst, OSSE detector 1 was viewing Cygnus X-1, detector 4 was viewing Cygnus X-3, and detectors 2 and 3 were observing a background field between these two targets. The burst was strongly observed in the latter two detectors and weakly seen in the former.

Plotted in Figure 3 are the count-rate spectra observed in detectors 1 and 2 during the time interval shown in Fig. 2, after backgrounds obtained within about a minute of the burst have been subtracted. No corrections have been made for detector efficiency. The spectrum observed in detector 2 exhibits a hard continuum which extends to $\sim$2 MeV. A similar spectrum was obtained for detector 3, which viewed the same source region. No significant line features are present in either spectrum. Only limited information can be inferred about the shape of the continuum until the spectra are corrected for the instrumental response for the location of the burst (see discussion below).

The spectrum from detector 1 (and, similarly, detector 4) shows increasing attenuation <1 MeV, indicating that the source's location was outside the aperture of the collimator in the scan direction (3.8° FWHM). The apparent increase in radiation below a few hundred keV is attributed to higher energy photons scattering into the detector. We have compared the rates observed in the four detectors with the measured angular responses during calibration to ob-

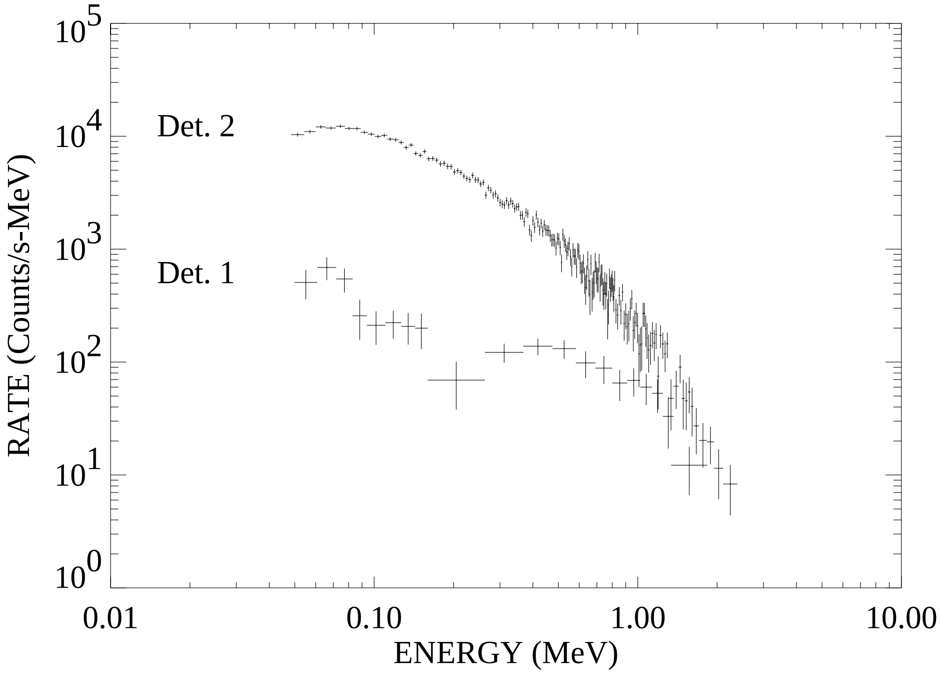

Figure 3. Background-corrected count-rate spectra (see Fig 2 for accumulation period) for detectors 1 and 2. Data channels have been summed to a minimum of 2σ above background.

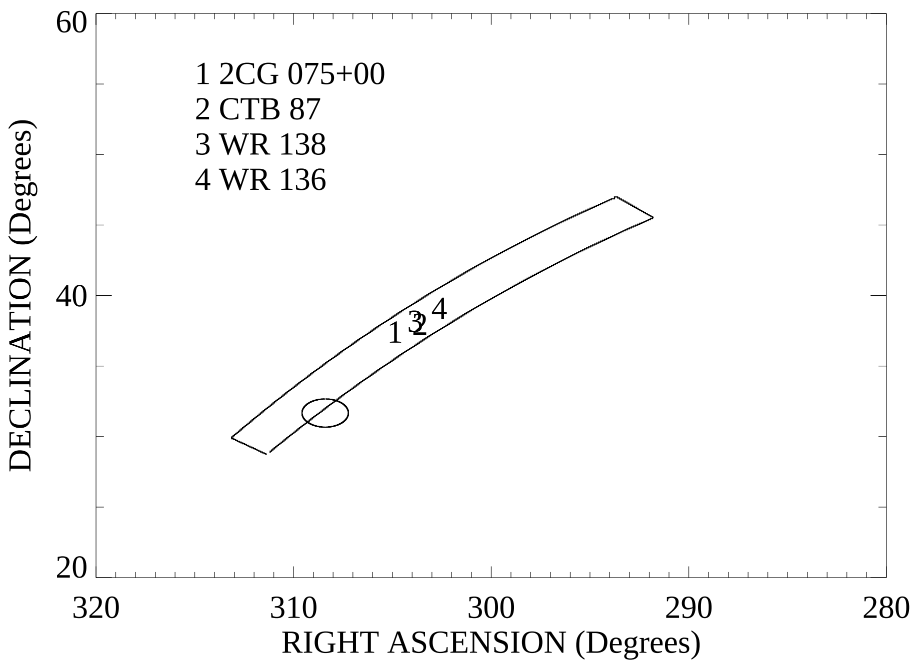

Figure 4. Error box for the source of the June 1 burst derived from OSSE observations. The circle is the COMPTEL position. Possible high-energy sources in the OSSE box are identified.

tain a source-location box for this burst. Almost identical rates were observed in detectors 1 and 4, which were offset $+4.4$ ° and -4.4 ° from detectors 2 and

3. This enabled us to infer that the source of the burst was within a scan angle of 1° from the axes of detectors 2 and 3. Possible source locations for this burst lie within the box plotted in Figure 4. Also shown is the error circle derived for this burst by COMPTEL[3]. The OSSE box appears to exclude about half of the COMPTEL circle. An improved source location will be available by triangulation using data from Ulysses and PVO. Based on the current source location, we estimate that this burst had a fluence of $\sim 10^{-4}$ erg cm^{-2} >50 keV.

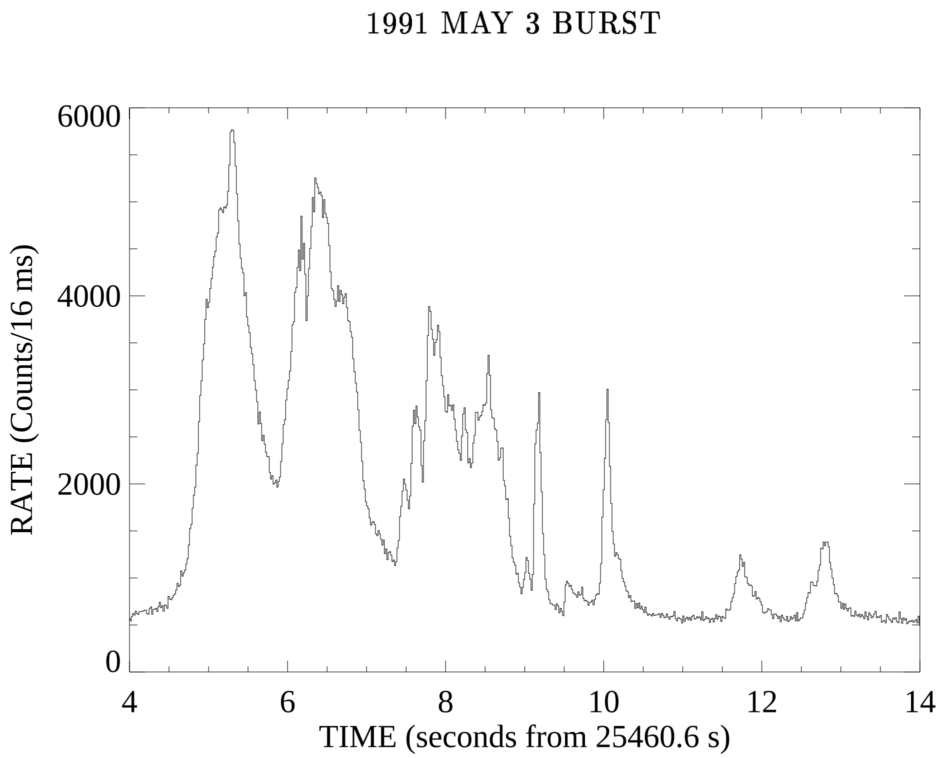

Figure 5. Count rates >100 keV recorded at 16 ms resolution by OSSE annular shields from the first part of the May 3 burst.

The May 3 event was the most intense observed to date by the *Compton Observatory* and is the subject of other papers in this Proceedings. The total shield counting rates >100 keV observed by OSSE during 10 s at the peak of the burst are plotted in Figure 5. Rates in excess of 5000 events in 16 ms were recorded and temporal variations on timescales of tens of ms are evident. Based on the location for this event obtained by COMPTEL[3], the source was $\sim 20^o$ off-axis perpendicular to OSSE's scan direction (11.4° aperture) and $\sim 3°$ from detector 2's axis in the scan direction (3.8° aperture). Thus much of the incident radiation has been absorbed or scattered to lower energies before reaching the central detectors. The count spectrum observed from this burst in detector 2 is shown in Fig. 6. Radiation up to ~30 MeV was observed; the effects of very strong absorption in the collimator and shielding is evident below 500 keV. The increase seen below 200 keV is attributed to scattered higher-energy radiation.

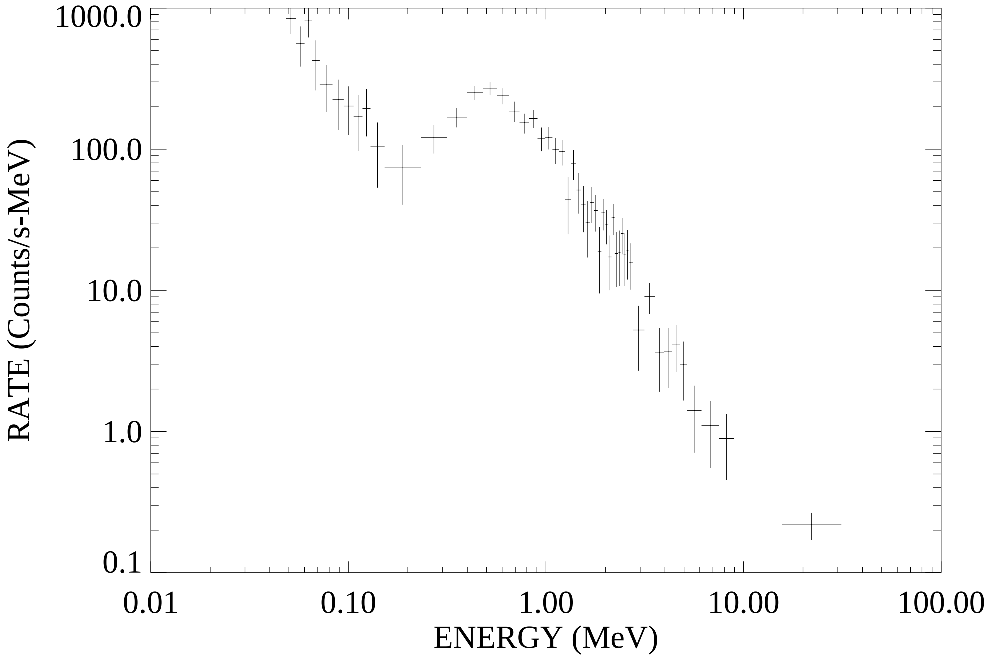

Figure 6. Background-corrected count-rate spectra of May 3 burst observed in detector 2. Burst location was outside aperture; only significantly absorbed and scattered radiation is observed, and give rise to the broad features observed.

PLANS FOR FUTURE STUDIES

Various studies are planned utilizing the OSSE data set on cosmic bursts. These include:

1. Determination of incident photon spectra for bursts observed within the aperture of an OSSE detector.
2. Temporal studies of bursts >100 keV at 16 ms observed in the shields.
3. Spectral evolution studies where high-time resolution data are available (for example 4 ms phoswich data from the May 3 event are available for comparison with the 16 ms data obtained >100 keV in the shields).
4. Studies of spectra from 0.1 to 8.0 MeV obtained from shield elements. Currently two 64 s spectra are accumulated in response to a BATSE trigger. Plans are being made to accumulate multiple spectra at higher time resolution.
5. An independent search for weak bursts ($\sim$1 x 10^{-7} erg/cm^2) in both OSSE's central detectors and shield elements is planned by searching the full data base for coincident events.

REFERENCES

1. W.N. Johnson, *et al.*, Proceedings of the *GRO* Science Workshop (W.N. Johnson, ed., 1989), p. 2-22.
2. R.A. Cameron, *et al.*, Proceedings of the *Compton Observatory* Science Workshop (In Press, *GRO* Science Support Center, 1991).
3. V. Schönfelder,*et al.*, Circ. 1085 (Bur. for Astr. Telegrams, 1991).